

Chapter 7

Recent Advances on Graph-Based Image Segmentation Techniques

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ABSTRACT

Image segmentation techniques using graph theory has become a thriving research area in computer vision community in recent years. This chapter mainly focuses on the most up-to-date research achievements in graph-based image segmentation published in top journals and conferences in computer vision community. The representative graph-based image segmentation methods included in this chapter are classified into six categories: minimum-cut/maximum-flow model (called graph-cut in some literatures), random walk model, minimum spanning tree model, normalized cut model and isoperimetric graph partitioning. The basic rationales of these models are presented, and the image segmentation methods based on these graph-based models are discussed as the main concern of this chapter. Several performance evaluation methods for image segmentation are given. Some public databases for testing image segmentation algorithms are introduced and the future work on graph-based image segmentation is discussed at the end of this chapter.

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INTRODUCTION

In computer vision applications, image segmentation is to separate an image into several regions, of which each has certain properties in terms of predefined rules. These regions can represent objects, parts of an object, or background. The aim of image segmentation is to find the regions of interest (ROI) in an image according to a particular application.

As a very important technique in computer vision, image segmentation has been found in a wide variety of practical applications, such as medical image processing, satellite image analysis, biometric recognition (e.g. human face recognition, fingerprint recognition and palm recognition), traffic control systems (e.g. vehicle number plate recognition, vehicle counting), digital photo editing, robotic vision and so on. Image segmentation approaches include clustering methods (Mignotte, 2008), compression-based methods (Rao, 2009), histogram-based methods (Otsu, 1979), edge detection methods (Senthilkumaran, 2009), region growing methods (Fan, 2005), partial differential equation-based methods (Zhang, 2010), graph-based methods (Boykov, 2001), watershed transformation methods (Grau, 2004) and so on. Among these image segmentation methods, the graph-based approach has attracted many attentions and become one of the most thriving research areas in computer vision in recent years. Meanwhile, many high quality papers on graph-based image segmentation techniques have been published in top journals and conferences in the field of image processing and computer vision. Therefore, this chapter is to gather the information on the most up-to-date graph-based image segmentation research together and give a clear overview of research work on this topic.

The remaining parts of this chapter are arranged as follows. Firstly, the background mathematical knowledge of graph theory is given. We then present the five most representative graph-based

models used for image segmentation and classify them into two major groups based on whether interactions of users are involved. The summary of the reviewed methods are illustrated in Table 1. Then, methods used for evaluating segmentation performance are discussed. Some benchmark image segmentation datasets are introduced. Conclusions are given in the end.

BACKGROUND

Mathematically, a graph $G=(V,E)$ is composed of a set of nodes (or vertices) $v \in V$ and a set of edges $e \in E \subseteq V \times V$ connecting two nodes $v_i \in V$ and $v_j \in V$. There are two types of edges: undirected edge and directed edge. An undirected edge is an unordered pair of nodes $e_{\{v_i, v_j\}}$. A directed edge is an ordered pair of nodes $e_{(v_i, v_j)}$, in which v_i is called the starting node and v_j is called the ending node. The weight of an edge is a value assigned to the edge, which describes the relationship between the two nodes.

In graph-based image segmentation models, a node can be a pixel, a set of pixels with common characteristics, a super pixel, or a feature vector of the pixel. The edge weight w is defined to describe the similarity or dissimilarity of two nodes connected by it according to the specific application.

The categorization of graph-based image segmentation techniques can be seen from Figure 1. Following this structure, the image segmentation techniques based on the five models will be discussed one by one. The relative graph theory knowledge will be presented at first. Then, the detailed content of different techniques will be shown. Meanwhile, the above mathematical notations of graph, node and edge will be used in the following content.

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